with that of stones of which the falls were witnessed: the proportion being only about 4 or 5 per cent. Thus in the collection at the British Museum we have 106 specimens of iron (siderites and siderolites together) indubitably meteoric, of which four only were seen to fall, while there are 179 of meteoric stones, of which only five have *not* been seen to fall. Surely, however, we have a sufficient explanation of this in the nature of the bodies themselves. The one, a mass of solid iron, besides possessing far greater permanence than a soft and porous rock permeated by small particles of readily rusting metal, would, if lying on the ground, be at once recognised by any one familiar with the metal, and would be preserved for use or as a curiosity; while the meteoric stone so found would equally naturally be neglected, unless the finder knew a meteorite as well as M. Meunier. Hence the iron mèteorite is both better preserved and more surely recognised; and hence though its fall is a far rarer event in nature than that of the meteoric stone, our collections are comparatively rich in iron meteorites. That the American Continent has furnished so many meteoric irons to our collections is, no doubt, due to the ignorance of the uses of iron on the part of the ancient inhabitants of that continent, and to the comparatively unpeopled nature of the country. It is in the United States, and scattered over the plains and valleys of Mexico, or lying unrusted under the clear dry air of the Cordilleras of the Andes, that most of these iron masses have been found. They afford an ocular proof that, though after a longer or shorter time such irons must sink into a shapeless mass of oxides, yet under favourable conditions they can and do last through long generations before this destructive process is consummated. Indeed, if they do not, what becomes of M. Meunier's main argument? And if they do, the anomaly of their coming into our collections, while the stones, the fall of which has not been witnessed, are absent, does not seem so inexplicable.

M. Meunier advances another argument in support of his theory founded on the similarity of composition of certain meteorites that he has examined, and in which he recognises what he terms a stratification of different recurring varieties.

Assuming the correctness of this statement, we fail to see its logical connection with his theory. It is no new fact in the mineralogy of meteorites, whether of stone or iron, that the same minerals and combinations recur in them, and that certain of them look like chips from the same block. It is on this very account that a community of origin for those belonging to each group of them, if not indeed for the whole of even these groups themselves, has been so long suspected. But is not this a community of origin that links them not only one with another, but probably also to other bodies in space, and that by a much further reaching chain than one which would bind them down only to our tiny orb and its satellite? Indeed, the very remarkable parallelism between their constituent elements and those which have been revealed by prismatic analysis as existing in activity on the surface of the sun, gives to this question of the origin of meteorites an interest of that expectant kind which holds us, as it were, listening for the announcement of what may be the next new discovery in solar physics—some fact that may illuminate as by electric light the whole solar system, and, clearing up the mystery that surrounds the comets, the zodiacal light, the solar corona, and even our aurora, may tell us why the "fiery tears of St. Lawrence" and other meteor showers do not descend on us as νιφάδες πέτρων, and even explain the source whence the meteorites do really come. We shall then be able better to decipher the characters in which the history of the meteorites is written, a history which assuredly is engraved, though in hieroglyphic language, on these messengers from space to our world. Expectation of this kind should surely invest our reasoning with the kind of caution which befits men who, feeling in the twilight after a "quest" of this kind, are conscious that they cannot be very far off from touching it in very truth, and, as it were, with their hands. We venture to think that M. Meunier has not, on this occasion, succeeded in attaining to the object of that quest.

N. S. MASKELYNE

WHAT IS ENERGY?

II.

IN our first article it was shown that energy, or the power of doing work, is of two kinds, namely, energy due to actual motion, and that due to position. We ended by supposing that a stone shot vertically upwards had been caught at the summit of its flight and lodged on the top of a house; and this gave rise to the question, What has become of the energy of the stone? To answer this we must learn to regard energy, not as a *quality*, but rather as a *thing*.

The chemist has always taught us to regard quantity or mass of matter as unchangeable, so that amid the many bewildering transformations of form and quality which take place in the chemical world, we can always consult our balance with a certainty that *it* will not play us false. But now the physical philosopher steps in and tells us that energy is quite as unchangeable as mass, and that the conservation of both is equally complete There is, however, this difference between the two things—the same particle of matter will always retain the same mass, but it will not always retain the same energy. As a whole, energy is invariable, but it is always shifting about from particle to particle, and it is hence more difficult to grasp the conception of an invariability of energy than of an invariability of mass. For instance, the mass of our luminary always remains the same, but its energy is always getting less.

And now to return to our question,—What has become of the energy of the stone? Has this disappeared? Far from it; the energy with which the stone began its flight has no more disappeared from the universe of energy, than the coal, when we have burned it in our fire, disappears from the universe of matter. But this has taken place:—the energy has changed its form and become spent or has disappeared as energy of actual motion, in gaining for the stone a position of advantage with regard to the force of gravity.

If we study this particular instance more minutely, we shall see that during the upward flight of the stone its energy of actual motion becomes gradually changed into energy of position, while the reverse will take place during its downward flight, if we now suppose it dislodged from the top of the house. In this latter case the energy of position with which it begins its downward flight is gradually reconverted into energy of actual motion, until at last, when the stone reaches the ground, it has the same amount of velocity, and, therefore, of actual energy, which it had at first.

Let us now revert, for a moment, to the definition of energy, which means the power of doing work, and we shall see at once how we may gauge numerically the quantity of energy which the stone possesses, and in order to simplify matters, let us suppose that this stone weighs exactly one pound. If therefore, it has velocity enough to carry it up one foot, it may be said to have energy enough to do one unit of work, inasmuch as we have defined one pound raised one foot high to be one unit of work; and in like manner if it has velocity sufficient to carry it 16 feet high, it may be said to have an energy equivalent to 16 units of work or foot-pounds as those units are sometimes called. Now, if the stone be discharged upwards with an initial velocity of 32 feet per second, it will rise 16 feet high, and it has therefore an energy represented by 16. But if its initial velocity be 64 feet per second it will rise 64 feet high before it turns, and will therefore have energy represented by 64. Hence we see that by doubling the velocity the energy is quadrupled, and we might show that by tripling the velocity the energy is increased nine times. This is expressed in general terms by saying that the energy or quantity of work which a moving body can accomplish varies as the square of its velocity. This fact is well known to artillerymen, for a ball with a double velocity will penetrate much more than twice as far into an obstacle opposing its progress.

Let us now take the stone or pound-weight having an initial velocity of 64 feet per second, and consider the state of things at the precise moment when it is 48 feet high. It will at that moment have an actual velocity of 32 feet per second, which, as we have seen, will represent 16 units of work. But it started from the ground with 64 units of work in it: what therefore has become of the difference—or 48 units? Evidently it has disappeared as actual energy; but the stone, being 48 feet high, has an energy of position represented by 48 units; so that at this precise moment of its flight its actual energy (16), *plus* its energy of position (48), are together equal to the whole energy with which it started (64).

Here, then, we have no annihilation of energy, but merely the transformation of it from actual energy into that implied by position; nor have we any creation of energy when the stone is on its downward flight, but merely the re-transformation of the energy of position into the original form of actual energy.

We shall presently discuss what becomes of this actual energy after the stone has struck the ground; but, in the meantime, we would repeat our remark how intimate is the analogy between the physical and the social world. In both cases we have actual energy and energy of position, the only difference being that in the social world it is impossible to measure energy with exactness, while in the mechanical world we can gauge it with the utmost precision.

Proteus-like, this element energy is always changing its form; and hence arises the extreme difficulty of the subject, for we cannot easily retain a sufficient grasp of the ever-changing element to argue experimentally regarding it. All the varieties of physical energy may, however, be embraced under the two heads already mentioned, namely, energy of actual motion and of position. We have chosen the force of gravity, acting upon a stone shot up into the air, as our example; but there are other forces besides gravity. Thus, a watch newly wound up is in a condition of visible advantage with respect to the force of the main-spring; and as it continues to go it gradually loses this energy of position, converting it into energy of motion. A cross-bow bent is likewise in a position of advantage with respect to the spring of the bow; and when its bolt is discharged, this energy of position is converted into that of motion. Thus again, a meteor, a railway train, a mountain torrent, the wind, all represent energy of actual visible motion; while a head of water may be classed along with a stone at the top of a house as representing energy of position. The list which represents visible energy of motion and of position might be extended indefinitely; but we must remember that there are also invisible molecular motions, which do not the less exist because they are invisible.

One of the best known of these molecular energies is *radiant light and heat*—a species which can traverse space with the enormous velocity of 186,000 miles a second.

Although itself eminently silent and gentle in its action it is, nevertheless, the parent of most of the work which is done in the world, as we shall presently see when we proceed to another division of our subject. In the mean time we may state that radiant light and heat are supposed to consist of a certain undulatory motion traversing an etherial medium which pervades all space.

Now, when this radiant energy falls upon a substance, part of it is absorbed, and in the process of absorption is converted into *ordinary heat*. The undulatory motion which had previously traversed the thin ether of space has now become linked with gross palpable matter, and manifests itself in a motion which it produces in the particles of this matter. The violence of this rotatory or vortex-like motion will thus form a measure of the heat which the matter contains.

Another species of molecular energy consists of *electricity in motion*. When an electric current is moving along a wire, we have therein the progress of a power moving like light with enormous velocity, and, like light, silent in its operation. Silent, we say, if it meets with no resistance, but exceedingly formidable if it be opposed; for the awe-inspiring flash is not so much the electricity itself as the visible punishment which it has inflicted on the air for daring to impede its progress. Had there been a set of stout wires between the thunder-cloud and the earth, the fluid would have passed into the ground without disturbance.

The molecular energies which we have now described may be imagined to represent motion of some sort not perceived by the outward eye, but present nevertheless to the eye of the understanding, they may therefore be compared to the energy of a body in visible motion, or actual energy as we have termed it.

But we have also molecular energies which are more analogous to the energy of position of a stone at the top of a cliff.

For instance, two bodies near one another may be endowed with a species of energy of position due to *opposite electrical states*, in which case they have a tendency to rush together, just as a stone at the top of a cliff has a tendency to rush to the earth. If the two bodies be allowed to rush together this energy of position will be converted into that of visible motion, just as when the stone is allowed to drop from the cliff its energy of position is converted into that of visible motion.

There is finally a species of molecular energy caused by *chemical separation.* When we carry a stone to the top of a cliff, we violently separate two bodies that attract one another, and these two bodies are the earth and the stone. In like manner when we decompose carbonic acid gas into its constituents we violently separate two bodies that attract one another, and these are carbon and oxygen. When, therefore, we have obtained in a separate state two bodies, the atoms of which are prepared to rush together and combine with one another, we have at the same time obtained a kind of energy of molecular position analogous on the small scale to the energy of a stone resting upon the top of a house, or on the edge of a cliff on the large or cosmical scale.

BALFOUR STEWART

FORMS OF ANIMAL LIFE

Forms of Animal Life; being Outlines of Zoological Classification, based upon Anatomical Investigation, and illustrated by Descriptions of Specimens and of Figures. By George Rolleston, D.M., F.R.S., Linacre Professor of Anatomy and Physiology in the University of Oxford. (Oxford: Macmillan and Co., 1870; Clarendon Press Series.)

I.

THIS long-promised and hoped-for book has at last appeared, and we may say at once that it fully maintains the well-earned reputation of its learned author. It will probably be most useful to his own pupils, for whom it seems to have been originally designed; and to those students of Comparative Anatomy who teach as well as learn.

The work consist of three parts: first, an enumeration of the anatomical characters of each sub-kingdom and class, arranged in a descending order from Mammalia to Gregarinæ—a plan less useful in most respects than the reverse one which is now generally followed. Next comes a minute description of certain dissected specimens in the new Museum at Oxford; and lastly an explanation of twelve plates, most of them original, which together supply a tolerably detailed account of the anatomy of at least one specimen of almost every class. "The distinctive character of the book consists in its attempting so to combine the concrete facts of Zöotomy with the outlines of systematic classification, as to enable the student to put them for himself into their natural relations of foundation and superstructure. The foundation may be made wider, and the superstructure may have its outlines not only filled up, but even considerably altered by subsequent and more extensive labours; but the mutual relations of the one as foundation and of the other as superstructure, which this book particularly aims at illustrating, must always remain the same." (Preface, p. vi.) This is very true, and it would have been well if all systems of classification had been thus based on anatomical facts. We may even suggest that the mutual relation of the foundation and the superstructure would have been still more obvious if the anatomical had preceded the systematic parts of the present work.

We propose, however, to follow Professor Rolleston's order, and to discuss here the classification he adopts, reserving an account of the second and third parts for a future article.

The question whether a perfect Zoological classification would be merely, like a perfect Nosology, a convenient method of stating and remembering a number of concomitant variations, or whether it would represent real genealogical relations between the several groups of animals, is one which has acquired great importance since the facts adduced by Darwin and Wallace have given probability to a modified form of the old theory of evolution. Most German naturalists fully accept this hypothesis, and employ their skill in constructing genealogical trees of each class. Dr. Rolleston holds that acceptance or rejection of the modern theory of evolution will depend on the particular constitution of each mind to which it is presented: "but," he adds, "whether the general theory be accepted as a whole or not, it must be allowed that in the face on the one hand of our knowledge of the greatness of the unlikeness which may be compatible with specific identity, and on the other of our ignorance of the entirety of the geological record, the value of the special 'phylogenies' reaching far out of modern periods are [qy. is] likely to remain in the very highest degree arbitrary and problematical."

It must, however, be remembered that, apart from its truth, a scientific theory may be very valuable by the accumulation of facts and the clearing of conceptions, to which it leads. Judged by this standard, the Darwinian theory is abundantly justified, not only by the observations of its illustrious author himself, but by the mass of excellent work it has evoked from others, especially in Germany. Indeed, from the results already gained, we may almost rank the theory of Natural Selection on a level with the teleological views which led Harvey to his great discovery, or with the belief in ideal archetypes by which Goethe was led to discover the presence of a præmaxillary bone in man, the "vertebral" construction of the skull, and the true morphology of a flower.*

Again, Dr. Rolleston enumerates the many similes by which men have endeavoured to represent the system of nature, and prefers the comparison of the groups of animals to the islands of an archipelago. Most readers will probably find the metaphor of a tree with its branches more useful, especially if existing forms are regarded according to Prof. Flower's ingenious suggestion, as the transverse section of such a tree, cut off at the present stage of the world's history. But, after all, by far the most natural, convenient, and almost inevitable metaphor

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* Die Descendenztheorie wird so eine neue Periode in der Geschichte der vergleichenden Anatomie beginnen. Sie wird sogar einen bedeutenderen Wendepunct bezeichnen als irgend eine Theorie in dieser Wissenschaft vorher vermocht hat, denn sie greift tiefer als alle jene, und es gibt kaum Einen Theil der Morphologie, der nicht auf's Innigste von ihr berührt würde. (Gegenbaur; Grundzüge der Vergl. Anat. 1870, p. 19.)